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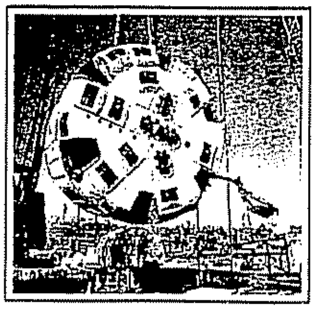
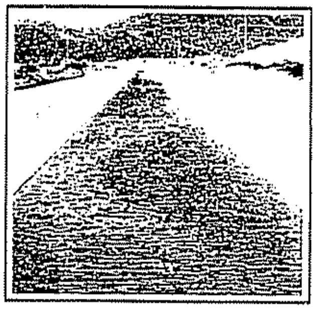
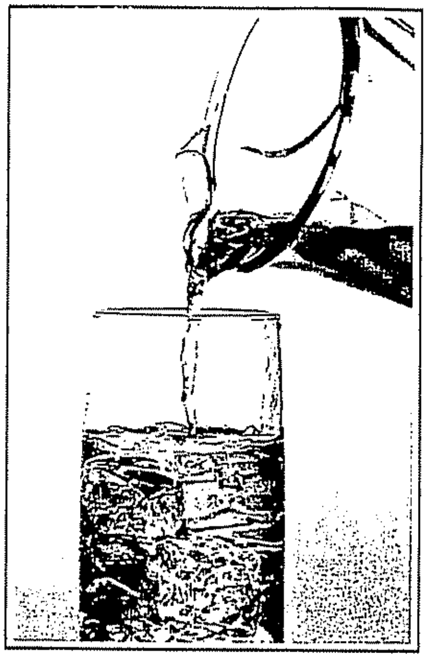
San Diego County Water Authority

Feasibility Level Engineering for Facilities to Transfer Water from The Imperial Irrigation District







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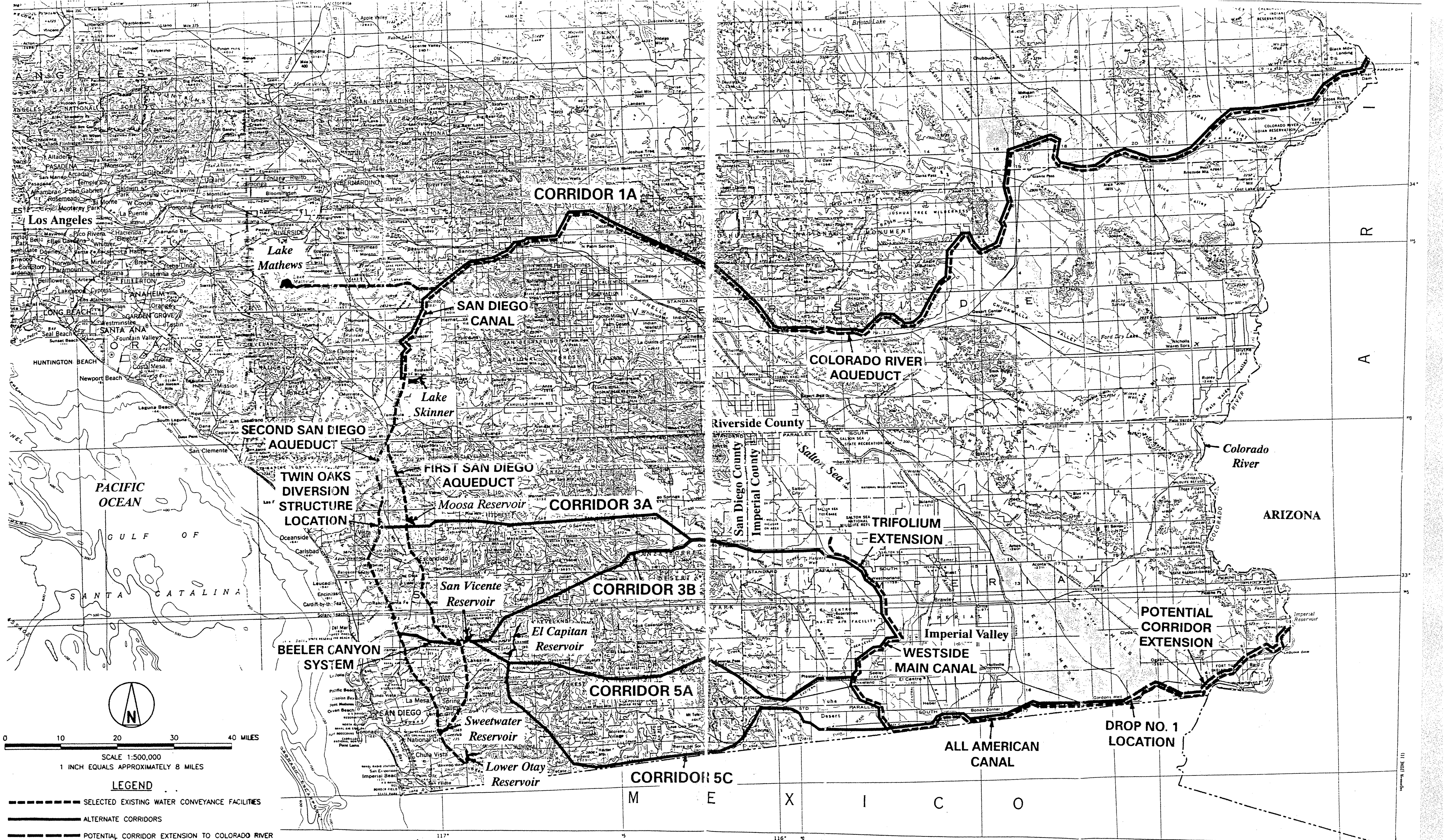
Woodward-Clyde

September 1996



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San Diego County Water Authority

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IID WATER TRANSFER STUDY

ALTERNATE CORRIDORS

FIGURE 2-1

San Diego County Water Authority

Feasibility Level Engineering for Facilities to Transfer Water from The Imperial Irrigation District

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EXP. 7/30/97
CIVIL
STATE OF CALIFORNIA

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of California.

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Date 9/30/96 Reg. No. 22299

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Executive Summary

ES.1 Introduction

The San Diego County Water Authority (Authority) was organized on June 9, 1944, to provide a safe and reliable water supply to the San Diego region. The Authority consists of 24 member agencies, including 6 cities, 16 special districts, and the Pendleton Military Reservation. The County of San Diego is a nonvoting, ex officio member of the Authority.

The 2100 Plan is a program the Authority is investigating to provide a reliable, high quality, supplemental water supply sufficient to meet the needs of the San Diego County Water Authority's service area through the year 2100. The Authority and the Imperial Irrigation District (IID) signed a Memorandum of Understanding in September 1995 to negotiate the terms of an agreement with a goal of transferring up to 500,000 acre-feet (AF) per year from IID to the Authority. One of the major issues in the negotiations is the cost to the Authority of purchasing and transporting this water to its service area.

The purpose of this feasibility-level engineering study is to develop a range of costs for facilities to transfer water from the Colorado River to the San Diego County Water Authority.

As a whole, the various sections of this study represent a comprehensive evaluation of the probable range of capital and operation and maintenance costs for transferring water from IID to San Diego County. The Authority can use this data to evaluate the economic feasibility of such a program. The information contained in this feasibility report may assist the Authority in deciding whether or not to proceed with further evaluations.

ES.2 Alternate Corridors

Five alternate corridors were selected to represent the potential range of capital and annual costs for the feasibility level engineering study. A description of the five corridors follows. A summary of the corridor key characteristics is presented in Section 2.0 as Table 2-2. A map showing the alternate corridors is provided as Figure 2-1.

Corridor 1A

Corridor 1A begins at Lake Havasu and parallels the Colorado River Aqueduct (CRA) and San Diego Canal to Lake Skinner. From Lake Skinner to the Twin Oaks Diversion Structure (TODS), it is envisioned that the Authority's existing pipelines in the

Second Aqueduct and future Pipeline 6 will convey the planned flow. This alternative consists of approximately 240 miles of canals, pipelines, siphons, and tunnels from Lake Havasu to Lake Skinner.

Corridor 3A

Corridor 3A begins at Drop No. 1 on the All-American Canal and parallels the All-American, Westside Main, and Thistle Canals to the southwest side of the Salton Sea to a point near the intersection on Highway 78 and San Felipe Creek. At this point, the corridor extends westerly along Highway 78 passing through Lower Borrego Valley. West of Desert Lodge, a 42 mile long tunnel extends westerly past Ranchita and south of Lake Henshaw, passes south of Moosa Canyon, and terminates east of Interstate 15. A short tunnel under I-15 and another 3 mile long tunnel segment would terminate the corridor at the TODS. Water storage would be provided in the proposed Moosa Reservoir, located in Moosa Canyon. The total length of this corridor is approximately 171 miles.

Corridor 3B

Corridor 3B begins at Drop No. 1 on the All-American Canal and parallels the All-American, Westside Main, and Thistle Canals to the southwest side of the Salton Sea to a point near the intersection on Highway 78 and San Felipe Creek. At this point, the corridor extends westerly along Highway 78 passing through Lower Borrego Valley to Sentenac Canyon. A 2 mile long tunnel would be constructed parallel to Highway 78 to bypass a narrow canyon on San Felipe Creek. From the west tunnel portal, the corridor extends southwesterly to Banner. From Banner, a tunnel extends to San Vicente Reservoir. The corridor would utilize the Beeler Canyon System from San Vicente Reservoir to the Authority's Second Aqueduct. The Beeler Canyon System, as developed for the Emergency Storage Project evaluations, originates on the west side of San Vicente Reservoir and terminates at the Second Aqueduct near Mercy Road. A pumping plant near San Vicente Reservoir would be provided to lift the water to match operating heads at the Second Aqueduct. The total length of this corridor is approximately 173 miles.

The costs for the Beeler Canyon System facilities are accounted for in the Emergency Storage Project cost estimates and are, therefore, not included in the corridor cost estimates. The ESP cost estimate for these facilities is provided in Section ES.11.3 for information.

Corridor 5A

Corridor 5A begins at Drop No. 1 on the All-American Canal and parallels the All-American Canal to the Westside Main Canal, then extends north along the Westside Main Canal to Dixieland. The corridor then extends westerly and parallels the San Diego and Arizona Eastern Railroad through Ocotillo to the base of the Jacumba Mountains. From this point, a tunnel would extend in a northwesterly direction through Chocolate Canyon south of El Capitan Reservoir and continue westerly to San Vicente Reservoir. The corridor would utilize the Beeler Canyon System between San Vicente Reservoir and the Second Aqueduct. The total length of this corridor is approximately 140 miles.

Corridor 5C

This corridor begins at Drop No. 1 on the All-American Canal and parallels the All-American Canal to its terminus. At this location, the corridor extends west through privately owned land for a short distance, then crosses BLM land. The route intersects SR 98 and follows the right-of-way to the community of Ocotillo. From Ocotillo, the route generally parallels SR 94 to Oasis, then westerly to Jacumba, and parallels the United States and Mexico border to Campo. At Campo, the route follows a northwesterly alignment south of Barrett and Loveland Reservoirs, west of the City of Alpine to Chocolate Canyon south of El Capitan Reservoir. In Chocolate Canyon, the corridor extends northwesterly to San Vicente Reservoir. The corridor would utilize the Beeler Canyon System between San Vicente Reservoir and the Second Aqueduct. The total length of this corridor is approximately 150 miles.

Potential Extension to Colorado River

As indicated above, Corridors 3A, 3B, 5A, and 5C begin at Drop No. 1 on the All-American Canal. However, consideration is also given in this study to extending each of these corridors eastward with a new canal aligned parallel to the All-American Canal between Drop No. 1 and the Colorado River at Imperial Dam, an additional distance of approximately 36 miles. This potential corridor extension may offer operational and water quality benefits to the Authority when compared to use of the All-American Canal between Drop No. 1 and the Colorado River. The estimated costs for the canal extension are provided in Section ES.11.3.

ES.3 Land Use

Land use issues associated with Corridor 1A have not been evaluated. Jurisdictional land use permitting issues associated with Corridors 3A, 3B, 5A, and 5C were identified using existing land use information and through contacts with the appropriate staff at the relevant agencies. Land use issues were identified from Imperial Dam to either the Second Aqueduct (Corridor 3A), or to San Vicente Reservoir (Corridors 3B, 5A, and 5C). Land use issues for the Beeler Canyon System are addressed in the Draft EIR/EIS for the Emergency Storage Project. Following is a summary of the major jurisdictional land use issues associated with each of the candidate routes.

Corridor 3A may potentially require tunneling under the Anza-Borrego Desert State Park Sheep Canyon Wilderness Area. The California Department of Parks and Recreation has indicated that it might not permit a tunneled crossing of a state wilderness area. However, they have also indicated that a tunneled crossing could possibly be permitted if wilderness values were not adversely affected by the project. This can possibly be achieved; therefore, this issue requires further discussion with the Department. Corridor 3B would require trenched and tunneled crossings of Anza-Borrego Desert State Park and a possible trenched crossing of wilderness areas in the state park. Trenched and tunneled construction in the state park would require implementation of significant environmental mitigation measures. The trenched crossing of state park wilderness areas will probably need to be avoided by closely following State Highway 78 and San Felipe Creek.

Corridor 5A would require tunneled crossings of the Anza-Borrego Desert State Park, Jacumba Mountains Wilderness Area, similar to Corridor 3A.

There are no major jurisdictional land use permitting issues associated with the Candidate Route 5C. All of the candidate corridors avoid the crossings of Native American reservations.

ES.4 Geologic Characterization

Conceptual-level geologic evaluations were completed along the alternative corridors. The objectives of these studies were to evaluate the geotechnical conditions and potential geologic hazards along the corridors, identify key geotechnical issues impacting the feasibility and costs of the project, and develop conceptual layouts and construction cost estimates for the tunnel segments.

The geologic evaluations include a compilation and review of pertinent information from available sources and a limited field reconnaissance. Using this information, preliminary geologic strip maps were prepared identifying major soil and rock types, active fault crossings, and mapped landslides. Tunnel portal and shaft locations were identified based on preliminary hydraulic profiles, topography, land use constraints, and geotechnical considerations. Geologic tunnel profiles were prepared for each corridor and conceptual-level design engineering analyses were completed for the tunnels. These conceptual designs were then used as the basis for developing the tunnel construction cost estimates.

Construction of the canals, pipelines, and tunnels appear to be geotechnically feasible; however, there are several key issues which must be considered in the design and operation of the project. Nearly all of the tunnels will be excavated in hard crystalline granitic and metamorphic rock and will require high powered, hard rock tunnel boring machines. Due to the length of the tunnels (up to 42 miles) and the depth below the ground surface (up to 4,200 feet), intermediate access shafts and multiple construction contracts will be required for the longer tunnel reaches. All of the corridors must cross the seismically active San Jacinto and Elsinore fault zones. As currently planned, these active fault zones are crossed in pipeline with exception of Corridor 3A which crosses the Elsinore fault zone in tunnel. Depending on the specific location and its geological conditions, potential geologic hazards include seismic shaking, differential settlement, fault rupture, landslides, and liquefaction. Potential hazards associated with tunnel construction include elevated ground temperatures in the tunnels with high cover and the possibility of encountering hot water upwelling along faults and fractures. All of these potential hazards can be reduced or mitigated through proper design and construction procedures, with the possible exception of fault rupture on the Elsinore or San Jacinto fault zones.

ES.5 Energy Management Strategy Evaluation

Tradeoff analyses were performed comparing capital and annual costs associated with alternate energy management strategies for Corridors 3A, 3B, 5A, and 5C. Because Corridor 1A is combined with existing Colorado River Aqueduct operations, alternate energy management strategies are not an option. Alternate energy management strategies were selected based on time periods and energy rates associated with on-peak, mid-peak, and off-peak use periods as defined in the current Southern California Edison time-of-use rate schedule for large customers. For each energy management strategy, the design hydraulic capacity of the transfer system was determined based on an annual transfer volume of 400,000 acre-feet (AF) and the number of available pumping hours associated with the strategy. The alternate energy management strategies are summarized as follows:

- Uniform Annual Pumping--Pump at a constant rate throughout the year. Hydraulic capacity of 608 cfs.
- Avoid On-Peak Pumping--Pump only during mid-peak and off-peak use periods during both summer and winter. Hydraulic capacity of 645 cfs.

- Off-Peak and Summer Mid-Peak Pumping--Pump during off-peak periods of summer and winter seasons, and mid-peak periods of summer only. Hydraulic capacity of 880 cfs.
- Off-Peak Only--Pump only during off-peak use periods. Hydraulic capacity of 1,005 cfs.

Vertical and horizontal corridors were selected to establish the key features of the conveyance system including estimated lengths of canals, pipelines, and tunnels, as well as total dynamic pumping head (TDH) and net head available for energy recovery. Water conveyance systems were sized based on the hydraulic capacity associated with each energy management strategy.

Capital costs for major system components were estimated for each corridor and energy management strategy based on in-house cost data and recent cost estimates for similar projects. Annual costs, consisting of pumping demand and energy costs, and recovered energy cost savings were estimated using the Southern California Edison time-of-use rate schedule. The present worth of total estimated capital and annual costs were determined using a cash flow analysis and similar economic parameters used in the Authority's financial model:

- 30 Year Evaluation Period.
- 3 Percent Escalation Rate.
- 7 Percent Present Worth Discount Rate.

For each corridor, the "Uniform Annual" strategy resulted in minimum capital costs and maximum annual costs. On the other hand, the "Off-Peak Only" strategy resulted in minimum annual costs and maximum capital costs. Overall, the present worth of total estimated project costs was found to vary by less than 12 percent for the various energy management strategies considered.

Because total estimated project costs do not vary significantly with the alternate energy management strategies considered, the range of costs for transferred water will not be particularly sensitive to selection of one energy management strategy over another. The "Uniform Annual" strategy was selected for use in the feasibility-level evaluations because this strategy results in facilities with the lowest capital cost. The tradeoff analyses comparing capital and annual costs do not justify selection of a higher capital cost system.

ES.6 Water Quality and Treatment

The costs of improving water quality were evaluated based on the costs of treating All-American Canal water. Two alternatives were evaluated. The first produces a water quality which is comparable to the current Metropolitan Water District of Southern

California (MWD) supply. The second alternative produces a water quality which meets the current Safe Drinking Water Act (SDWA) recommended secondary standard of 500 mg/l for total dissolved solids (TDS). Two scenarios were considered for each alternative: 1) treatment in Imperial County (East Side alternatives) before the water is pumped and; 2) treatment in San Diego County (West Side alternatives), after it is pumped.

A preliminary review of the treatment costs only to improve water quality indicates that there is a cost advantage to locating the facilities in San Diego. The cost savings of these west side alternatives are derived from being able to take advantage of facilities already constructed (such as Miramar and Alvarado Water Treatment Plants) to provide pretreatment. Treatment to the SDWA recommended secondary standard of 500 mg/l was selected for use in the transfer system cost evaluations.

The reverse osmosis (RO) performance design program used in the evaluations of the selected alternative indicates that, for Corridors 3A, 3B, 5A, and 5C, approximately 13.3 percent of the transferred water will be consumed as brine disposal. For Corridor 1A, approximately 9.3 percent of the transferred water will be consumed as brine disposal. The difference in brine disposal requirements is related to the average salinity at the point of diversion. The average salinity of 747 mg/l at Parker Dam (Corridor 1A diversion) is lower than the average salinity of 879 mg/l at Imperial Dam (Corridors 3A, 3B, 5A, and 5C diversion), resulting in lower brine disposal requirements. Accounting for brine disposal requirements, the estimated annual deliverable water volume will be as follows:

Corridor	Transfer Volume (acre-feet)	Brine Disposal Volume (acre-feet)	Deliverable Volume (acre-feet)
1A - Stage 1	200,000	18,600	181,400
1A - Stage 2	300,000	27,900	272,100
3A, 3B, 5A, 5C	300,000	39,900	260,100
3A, 3B, 5A, 5C	400,000	53,200	346,800
3A, 3B, 5A, 5C	500,000	66,500	433,500

The following three possible disposal alternatives were considered:

- Dedicated brine disposal through piping to the San Diego River.
- Discharge to local sewers.
- Dedicated brine disposal pipelines from the Miramar and Alvarado WTPs to the South Bay Outfall

The environmental regulations and permitting issues associated with discharges to the San Diego River are very complex and uncertain and may preclude this option Discharge to local sewers with disposal to the Point Loma WWTP has been determined to be economically infeasible due to the exorbitant discharge fees arising from the high brine flow rates and TDS concentrations. In addition, it was determined that the existing sewers do not have capacity to accommodate the new brine flows. It is also doubtful the existing outfall capacity at the Point Loma WWTP is sufficient to accommodate the increased flows.

A preliminary review of the existing sewer capacity near Miramar and Alvarado indicates that construction of new gravity sewers and a pump lift station would be needed. A new gravity sewer would be needed to convey the brine discharge from Miramar to a new pump station located near the intersection of Highway 15 and Highway 8. In addition, a new gravity sewer would be required to convey brine from Alvarado to the new pump station. The brine would then be lifted by the pump station approximately 340 feet and then flow by gravity through a new 60 inch diameter, 17 mile long pipeline to the South Bay Outfall. The environmental, regulatory, and institutional complexities of brine disposal require further investigation before an apparent best alternative can be identified.

ES.7 Corridor Engineering Evaluations

Engineering aspects of the alternate corridors were evaluated, including development of concept designs for the major system features, including the following:

- Canals.
- Pipelines.
- Tunnels
- Pumping plants.
- Power generating facilities.
- Electric transmission lines.
- Water treatment facilities.

The concept designs developed during preparation of this study serve as a basis for the capital and first year annual operating costs that are presented in Section 11.0. The feasibility level engineering evaluations performed for each corridor are summarized as follows.

ES.7.1 Corridor 1A Evaluations

Corridor 1A is essentially the Colorado River Aqueduct from the Colorado River to the West Portal of the San Jacinto Tunnel. At the West Portal, the corridor will follow the San Diego Canal to Lake Skinner.

A staged project development approach was considered for the Corridor 1A evaluations. Stage 1 would modify segments of the CRA as required to increase the existing hydraulic capacity sufficiently to convey an additional transfer volume of about 200,000 acre-feet. Stage 2 would involve construction of a new aqueduct system parallel to the existing CRA to supply transfer volumes of 300,000 acre-feet. Development of this new system following expansion of the existing system would result in total annual transfer volume of 500,000 acre-feet. The concept designs and issues associated with each stage of development are summarized as follows.

Stage 1--CRA Expansion

Stage 1 development involves modifying segments of the CRA as necessary to increase the hydraulic capacity sufficiently to convey an additional annual volume of about 200,000 AF. The proposed modification requirements and issues are as follows.

Pumping Plants. The existing annual conveyance volume of the CRA was considered to be 1,200,000 AF. Therefore, Stage 1 development would result in a required annual conveyance volume of 1,400,000 AF. An annual weighted average pump availability of 8.33 pumps was determined to be required based on the maintenance schedule considered. To convey 1,400,000 AF/year with an average of 8.33 pumps, the average pump discharge capacity must be approximately 232 cfs. Total CRA flow for eight pump operation would be 1,856 cfs. Nine pump operation would result in CRA flow of 2,088 cfs.

The required pump discharge capacity approximately corresponds to the nominal pump discharge capacity resulting from the recent CRA Pump Rehabilitation Program. However, actual pump capacity will vary based on the relationship between net head and total system flow. An increase in net head above existing conditions would reduce pump capacity, whereas a decrease in net head would increase pump capacity.

The following modifications to the various CRA components were considered. For evaluation purposes, an existing CRA capacity of 1,780 cfs was used. A CRA capacity of 2,080 cfs, corresponding to a capacity increase of 300 cfs, was used to estimate the hydraulic characteristics of the modified system.

Tunnels. Because of the high cost associated with construction of new tunnels, allowing the existing tunnels to flow pressurized was considered. Pressurizing the tunnels during increased flow conditions will increase the slope of the hydraulic grade line (HGL) within each tunnel and result in an HGL elevation at the upstream ends higher than presently exists. Information is not available to indicate the flow depth within the tunnels for historical maximum discharge conditions; therefore, existing Manning's 'n' could not be directly determined. To estimate a range in Manning's 'n' values, the following alternate flow depths were evaluated for a discharge capacity of 1,780 cfs:

- Flow depth of 13.17 feet within a 16 foot tunnel. This corresponds to the original tunnel design flow depth. The resulting Manning's 'n' was determined to be 0.0117.
- Flow depth of 15.0 feet, corresponding to the maximum conveyance capacity of the tunnel (maximum $AR^{2/3}$). This resulted in a Manning's 'n' of 0.0125.

Canals. Existing canal depth is 11.71 feet. At a discharge of 2,080 cfs, water depth would be 11.63 feet, resulting in essentially no freeboard. For canal segments flowing at normal depth, the canal lining would be extended a vertical height of 1.5 feet to convey the increased discharge and to result in freeboard approximately corresponding to the original design conditions. Certain tunnel segments located upstream from tunnels require raising of the canal lining in excess of 1.5 feet to accommodate the higher HGL typically located upstream from tunnels.

Cut-and-Cover Conduits. These conduits, which were originally constructed in areas subject to flooding, blowing sand, or in deep cuts at tunnel portals, would be replaced entirely by new parallel canals since their design does not allow to operate them under pressure. Their replacement with canals would also moderate the increase of the hydraulic gradient produced by operating the existing tunnels under pressure to minimize the head increase on the pumps.

Inverted Siphons. Major crossings typically utilize inverted siphon structures, which have two barrels.

For evaluation purposes, the siphons whose existing maximum design head is exceeded by 25 percent or more would be replaced completely with new siphons of larger capacity able to pass the increased design flow. A third barrel would be added to all other siphons to result in approximately the same head loss with increased discharge as exists for current maximum discharge conditions.

Hydraulic Analysis. A hydraulic analysis of the CRA was performed to evaluate the effects of the proposed increase in CRA discharge and proposed modifications on the total head at each pumping plant. The hydraulic analysis was based on the hydraulic properties of the existing and modified components as described above and a discharge of 2,080 cfs.

Separate analyses were performed for alternate Manning's 'n' values in tunnels as follows:

- Case 1 - Tunnel Manning's 'n' of 0.0117.
- Case 2 - Tunnel Manning's 'n' of 0.0125.

Analyses based on these two values of Manning's 'n' are judged to result in the likely range of HGL elevations along the CRA and at each pumping plant Case 1 represents the "best case" scenario in terms of existing CRA hydraulic conditions and the modifications considered for the various CRA components to achieve the desired annual conveyance capacity. The results of the analyses are summarized as follows.

Pumping Plants. For Case 1 conditions ('n' = 0.0117), the increase in pump lift relative to existing conditions is less than or equal to 3.2 percent at all pumping plants except Iron Mountain, which would have an increase in pump lift of 9.7 percent. The relationships between total pumping plant discharge and net head have not been established. Therefore, the actual capability of the pumping plants to deliver 200,000 AF/year at the required average discharge of 232 cfs per pump under the Case 1 head conditions is unknown. For purposes of the Case 1 analysis, no additional modifications are considered to be required at any of the pumping plants at this time. Should additional modifications be determined to be required to deliver the full annual transfer volume, the incremental costs of these modifications should be compared to the incremental costs of delivering a reduced transfer volume without the additional modifications.

For Case 2 conditions ('n' = 0.0125), the increase in net head at Whitsett, Gene, and Eagle Mountain is less than or equal than 4.1 percent. No additional modifications are considered to be required at these pumping plants for the reasons indicated in the Case 1 discussion. As with Case 1, a potential consequence may be reduced transfer capability below the desired 200,000 AF per year. The net head increase at Iron Mountain and Hinds is 13.9 and 9.1 percent, respectively. The ability of the pumps at these pumping plants to operate satisfactorily under these head conditions is doubtful.

One potential alternative for increasing the discharge capacity at Iron Mountain and Hinds may be replacing the existing impellers with new impellers of higher discharge capacity and performing other necessary pumping plant modifications. Other alternatives that may provide a marginal increase in pump speed and discharge include installation of cyclo-converters in the power supply along with frequency conversion power electronics or installation of a load commutating inverter (LCI) system to provide a variable frequency electrical drive. However, evaluating the practicality of these alternatives is beyond the scope of this study.

Another alternative involves further modifying the conveyance system downstream from these pumping stations to reduce the pump lift required for the higher flow conditions A separate hydraulic analysis was performed based on construction of a new 18.3 mile long tunnel parallel to the Coachella Tunnel located downstream from Hinds, and construction of a new 8.3 mile long tunnel parallel to the Iron Mountain Tunnel located downstream from Iron Mountain Pumping Plant. The results of the hydraulic analyses indicate revised increases in pump lift at Hinds and Iron Mountain which are similar to the increases determined for the other pumping plants. Construction of these two new tunnels is considered to be required for Case 2 conditions. Additionally, for Case 2 conditions, the HGL at the upstream end of Whipple Mountain Tunnel would be about 3 feet above the Copper Basin elevation. Construction of a new 6 mile long tunnel parallel to the Whipple Mountain Tunnel would eliminate the need to raise the Copper Basin water surface elevation and is also considered to be required for Case 2 conditions.

Canals. Maximum canal depth as determined from the hydraulic analysis is approximately 40 feet for canals replacing cut-and-cover conduits. Since the canal invert would be at approximately the same elevation as the invert of the existing cut-and-cover conduit, maximum canal embankment height would be about 20 feet above existing grade. Existing canals were found to require a maximum depth of approximately 18 feet at certain locations upstream from tunnels.

Cut-and-cover conduits were originally constructed at locations where canal construction was determined to be undesirable for a variety of reasons, including hydrologic, topographic, and land use considerations. As a result, the design and operational impacts associated with the use of canals in lieu of the existing cut-and-cover conduits should be evaluated if further consideration is given to this stage of corridor development.

Stage 1 Development Considerations. Numerous institutional, environmental, and technical issues and challenges would have to be resolved to successfully implement Stage 1 development. The definitive evaluation of all of these items is beyond the scope of this study. Should the information presented in this study indicate that additional consideration of this corridor is warranted, further investigations should be performed to confirm the issues affecting project implementation, to refine the potential cost, and evaluate other environmental impacts that may result.

Stage 2--New Parallel System

This stage would involve development of a new gravity flow aqueduct system aligned generally parallel and adjacent to the existing CRA. The capacity of the new system would be 456 cfs, resulting in an annual transfer capability of 300,000 acre-feet. System components would be of similar construction to the existing CRA facilities. The following paragraphs summarize the corridor features.

Tunnels. New tunnels would be constructed at the locations and with the same invert slopes of existing CRA tunnels. Based on the tunnel concept designs developed as part of this study, the minimum finished tunnel diameter will be 9.5 feet. Tunnel diameter is controlled by the selected minimum bore diameter and not hydraulic considerations.

Reinforced Concrete Pipelines. Precast reinforced concrete pipelines with water-tight joints will be constructed along segments of the CRA that presently utilize cut-and-cover conduits. The RCP will have an inside diameter of 11 feet.

Canals. New canals will be constructed along canal segments of the existing CRA. The canals will be sized for a hydraulic capacity of 456 cfs based on the invert slope of the existing canals.

Siphons. Reinforced concrete pipe siphons will be constructed at locations where siphons are presently utilized. Dual-barrel, 7 foot diameter siphons have been selected.

Pumping Plants. New pumping plants will be constructed at the locations of existing pumping facilities. It is anticipated the pumping structures will be of similar construction to the pumping structures selected for the other four corridors considered in this evaluation.

ES.7.2 Corridor 3A, 3B, 5A, and 5C Evaluations

Each of these systems conveys water from the Colorado River to the Authority's Second Aqueduct.

Hydraulic Analysis

Several criteria were used for the preliminary hydraulic analysis; flow rate, Manning's n value, and maximum allowable pumping head. Based on uniform annual pumping operations, the required hydraulic capacity for each transfer volume was increased by 10 percent to establish the design hydraulic capacities of the canals, pipelines, and tunnels. A 10 percent factor was selected to provide approximately 1 month for annual maintenance and emergency outages. The annual transfer volumes, design flow rates, and required pipeline diameters to the nearest 6 inches are as follows:

Annual Transfer Volume (AF/year)	Design Hydraulic Capacity (cfs)	Pipeline Diameter (inches)
300,000	456	96
400,000	608	108
500,000	760	120

Tunnels

Due to the length of the tunnels and the required working space for ventilation ducts, pipes to pump out ground water inflows and room for muck railcars, a 12 foot minimum excavated diameter was selected. An unlined tunnel would be used where rock quality is considered to be sufficiently good and the cover over the tunnel is sufficient to prevent hydraulic jacking. A 12 inch thick unreinforced concrete lining would be used in sections where the rock quality is considered to be poor (e.g., through major fault zones). A steel lining would be used where hydraulic jacking is considered to be a potential problem. These various lined and unlined conditions result in three finished tunnel diameters: 12 feet for an unlined tunnel, 10 feet for a concrete-lined tunnel, and 9.5 feet for a steel-lined tunnel. Using this approach, tunnel diameter is the same for each transfer volume considered and is based on the 12 foot minimum excavated diameter

Concept Designs

Concept designs were developed based on the three alternate annual water transfer volumes indicated above. The following items were evaluated:

- Alignment and grade of canals, pipelines, and tunnels based on land use, geology, topography, and construction road access roads.
- Steady-state hydraulic conditions and preliminary hydraulic analysis of transient conditions.
- Tunnel excavation methods, methods of mechanical excavation, downtime, and tunnel advance rates.
- Ground support alternatives.
- Special ground stabilization options.
- Ground water inflows and discharge requirements and potential impacts on the environment.
- Trench backfill requirements/excess soil disposal.

Proposed Facilities Within IID Service Area. The transfer of water from IID to the Authority will require facilities to convey that water from the Colorado River to the Authority's service area. Conceptual designs investigated for Corridors 3A, 3B, 5A, and 5C consider that these corridors would extend west from alternate locations along the western boundary of IID. Alternatives for conveying water from the Colorado River to those locations range between two extremes: utilization of available capacity in the All-American Canal or construction of new, parallel conveyance facilities. To minimize costs, it would be to the Authority's advantage to utilize existing facilities to the greatest extent possible; however, practical considerations related to operational control, water quality, and system losses may make such an arrangement unattractive.

To evaluate transfer system costs, construction of a new canal from Drop No. 1 on the All-American Canal to the western boundary of the IID system was selected. The estimated additional costs for extending the new canal from Drop No. 1 to the Colorado River were also determined.

ES.7.3 Storage Reservoirs

A storage reservoir will be required for each corridor to provide daily operational storage, to balance variations in monthly supply and demand, and to provide storage for periods of scheduled and unscheduled pumping outages. The approach used to establish the reservoir active storage capacity is described in Section 5.0. An active capacity of 67,000 AF was selected for use with all transfer volumes.

For Corridors 3B, 5A, and 5C, the active storage would be provided by expansion of existing San Vicente Reservoir, as previously considered by the Authority for several alternatives associated with the Emergency Storage Project.

For Corridors 1A (Stage 2 only) and 3A, active storage would be provided by construction of a new reservoir located in the Moosa Canyon, also as previously considered for the Emergency Storage Project.

The costs for storage reservoirs are accounted for in the Emergency Storage Project cost estimates and are, therefore, not included in the corridor cost estimates. The ESP cost estimates for these facilities are provided in Section ES.11.3 for information.

ES.7.4 Pumping Plants

The feasibility level designs of the alternate corridors include pumping plants located in series to provide the energy required to overcome the changes in elevation and system head losses along each route. Total pumping head for the alternate corridors varies from approximately 1,600 to 4,000 feet, excluding the pumping head provided by the San Vicente Pumping Plant for Corridors 3B, 5A, and 5C. The number of pumping plants required for each corridor is as follows:

Corridor	Number of New Pumping Plants
1A (Expand CRA)	0
1A (New System)	5
3A	3
3B	5*

Corridor	Number of New Pumping Plants
5A	2*
5C	5*

*Excluding San Vicente Pumping Station associated with Beeler Canyon System.

Operational storage at each pumping plant will be provided in a forebay for normal startup and shutdown of the pumping plant, and for unscheduled outages of one or more pumps or pumping plants. Forebay storage will also serve to temporarily balance minor differences between total pumping plant discharge of individual pumping plants in series.

It is proposed that 60 minutes of operational storage at 100 percent design hydraulic capacity be provided between the minimum and maximum operating water surface elevations within the forebay. One-half of the total operational storage would be provided above the normal operating water surface elevation and one-half of total storage would be provided below the normal operating water surface elevation.

ES.7.5 Power Generating/Pressure Control Facilities

The feasibility level designs of Corridors 3B and 5C include power generating/ pressure control facilities located in series to recover energy and control system pressures due to the changes in elevation along each route. Total net power generating head is approximately 2,100 feet for Corridor 3B, and 2,350 feet for Corridor 5C. Power generating/pressure control facilities required for Corridors 3B and 5C are as follows:

Corridor	Facility No.	Net Head	Powerhouse Type
3B	1	1,450	Underground
	2	650	Surface
5C	1	800	Surface
	2	800	Surface
	3	750	Surface

Operational storage will be provided in an afterbay located at each surface powerhouse for normal startup and shutdown of the power generating/pressure control facility, and for unscheduled outages of one or more power generating/pressure control facilities. Afterbay storage will also serve to temporarily balance minor differences between total facility discharge of individual power generating/pressure control facilities in series. The afterbays will be sized as described for the pumping plant forebays

ES.7.6 Electric Transmission Lines

New transmission lines are not anticipated to be required for Stage 1 development of Corridor 1A, however, new transmission lines are included for Stage 2 development.

The transmission lines supplying power to the pumping stations for Corridors 3A, 3B, 5A, and 5C are assumed to have a voltage of 230 kV. The transmission lines carrying power away from the proposed power generation/pressure control facilities are assumed to have a voltage of 69 kV. For evaluation purposes, the project transmission facilities will be connected to the SDG&E system.

ES.8 Electric Power Market Analysis

To determine the potential availability and cost of electric power to meet the project's energy requirements, assessments were made to identify potential sources for such energy, to determine the capability of the existing transmission system to deliver energy, and to estimate anticipated market costs for purchasing and selling energy. The principal conclusions of these assessments are as follows:

- Energy will likely be available (from new resources or from a combination of new and existing resources) to serve the needs of the project pumps for approximately 3 cents/kWh, expressed in 1996 dollars. This price assumes that natural gas or an equivalent would be the fuel of choice. The price would escalate at an average annual rate of approximately 3 percent, unless the price of fuel should escalate at rates significantly higher than presently anticipated.
- Preliminary technical studies evaluating each of the five corridors considered indicate that:
  - With the addition of voltage support equipment, there would likely be sufficient capacity on the existing 230 kV system to serve 100 MW of pumping loads associated with an upgrade of the Colorado River Aqueduct.
  - Up to 320-375 MW could be delivered into the Imperial Valley from resources located east of the Colorado River without adversely affecting the local transmission system if this power was delivered utilizing portions of the existing transfer capability of the facilities between Arizona and southern California.
  - Up to 320-375 MW could be delivered to the pumping loads from resources in the SDG&E/IID areas without adversely affecting the

local transmission system if the necessary interconnection facilities are installed

ES.9 Natural Gas Market Analysis

To determine the availability and estimated cost of fuel for a potential project-dedicated electric generating facility, assessments were made of current and future natural gas reserves, pipeline transportation capacity, and the projected cost of natural gas delivered to the generating facilities expected location near Brawley, California. The principal conclusions of these assessments are as follows:

- Natural gas reserves in the United States and Canada are adequate to support southern California's future gas requirements and supply the quantity of gas estimated to be consumed by a potential generating facility.
- There is likely to be adequate interstate pipeline capacity available from southwest US and Canadian supply basins to the project. Southern California Gas Company (SoCalGas) stated that it could redeliver gas supplies from interconnections with the interstate pipelines to the Brawley area. SoCalGas also stated there is sufficient capacity within its pipeline system for the proposed project. The project will have the option of contracting separately for gas transportation and commodity services with pipelines and suppliers, respectively, or contracting with gas suppliers for "bundled" commodity and transportation services.

ES.10 Environmental Assessments

Environmental permitting issues associated with Corridor 1A have not been evaluated. Environmental permitting issues associated with Corridors 3A, 3B, 5A, and 5C were identified using existing information on the locations and characteristics of important environmental resources; available information on the applicable federal, state, and local permitting requirements for these types of projects; and from experience in permitting these types of projects in southern California and other geographic areas. The analysis includes environmental permitting issues identified from Imperial Dam to either the Second Aqueduct (Corridor 3A), or to San Vicente Reservoir (Corridors 3B, 5A, and 5C). Environmental permitting issues for the Beeler Canyon System are addressed in the Draft EIR/EIS for the Emergency Storage Project. The analysis addresses biological resource issues for only the pipeline segments of the corridors, since tunneling is not expected to impact biological resources.

The potential presence of numerous sensitive species and habitats along all of the corridors indicates that compliance with both the Federal and State Endangered Species Acts will be required for the implementation of the proposed project along these candidate corridors. Permitting agencies for Federal and State Endangered Species Act compliance include the US Fish and Wildlife Service (USFWS) and the California Department of Fish & Game (CDFG), respectively.

The potential presence of substantial wetlands and waters of the US along all of the corridors indicates that compliance with both Section 404 of the Federal Clean Water Act and Section 1600 of the California Fish & Game Code will be required for implementation of the proposed project. Permitting agencies for wetland permitting include the US Army Corps of Engineers (ACOE) and CDFG.

The potential presence of numerous sensitive cultural resources along all of the corridors indicates that compliance with Section 106 of the National Historic Preservation Act (NHPA), the Native American Graves Protection and Repatriation Act (NAGPRA), and the American Indian Religious Freedom Act (AIRFA). The permitting agency for all cultural resource compliance would likely be BLM or USFS.

National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) compliance for the project could be met through the preparation of an EIR/EIS that analyzes three or more alternatives to the project.

Corridors 3A, 3B, 5A, and 5C are judged to be permittable, from an environmental permitting perspective. Environmental permitting issues vary between each of the candidate corridors, mainly with respect to estimated mitigation costs.

ES.11 Opinion of Probable Costs

Opinions of probable capital and annual costs were prepared for the water transfer system facilities anticipated to be required for each corridor. For Corridor 1A, separate cost estimates were prepared for increasing the capacity of the existing CRA facilities to result in additional transfer capability of about 200,000 AF (Stage 1), and for construction of new parallel facilities with hydraulic capacity corresponding to an annual transfer volume of 300,000 AF (Stage 2). Total increased capacity would be 500,000 AF. Separate cost estimates were prepared for Corridors 3A, 3B, 5A, and 5C for annual transfer volumes of 300,000; 400,000; and 500,000 AF.

In accordance with the purpose of this study, the opinions of probable costs provided in this study define an estimated range of costs for facilities to transfer water from the Imperial Irrigation District to the San Diego County Water Authority. The cost opinions should be used for the exclusive purpose of determining whether additional investment in more detailed evaluations is warranted.

A summary of estimated capital and annual costs for each corridor is provided in Table ES-1. Estimated capital costs include the following system components:

- Canals.
- Pipelines.
- Tunnels.
- Pumping plants.
- Power generating/pressure control facilities.
- Electric transmission lines.
- Environmental permitting and mitigation.
- Water treatment facilities.
- Indirect costs.

Estimated annual costs include the following components:

- Pumping energy.
- Operation, maintenance, and replacement.
- Energy recovery.
- Water treatment.

For Corridors 3A, 3B, 5A, and 5C, a contingency factor of 50 percent was applied to the tunnel costs to reflect the preliminary nature of the geologic data on which the costs were based. A contingency factor of 20 percent was applied to water treatment costs. All other components were assigned a 25 percent contingency.

For Corridor 1A, a 35 percent contingency was applied to all components, except water treatment, to reflect the preliminary nature of the concept designs. As with the other corridors, water treatment costs were assigned a 20 percent contingency. A 35 percent contingency is appropriate for the Corridor 1A tunnels since the geologic conditions are better defined through construction of the existing CRA tunnels. A 15 percent allowance was applied to construction costs for all corridors to account for indirect costs, including engineering, administration, and construction management.

ES.11.1 Stage 1 Development of Corridor 1A

The costs presented in Table ES-1 for Stage 1 development represent a best case scenario in terms of existing CRA hydraulic conditions and the modifications considered for the various components of the CRA to achieve the additional annual conveyance capacity of 200,000 AF. For this best case scenario, no modifications are considered to be

Table ES-1
Summary of Estimated Costs*

Item	Annual Transfer Volume 200,000 AF ($1,000)	300,000 AF ($1,000)	400,000 AF ($1,000)	500,000 AF ($1,000)
Total Estimated Capital Costs				
Corridor 1A (Stage 1 - Expand CRA)**	889,711			
Corridor 1A (Stage 2 - New System)***		2,742,154		
Corridor 3A		1,981,309	2,124,110	2,276,204
Corridor 3B		1,520,756	1,716,415	1,913,912
Corridor 5A		1,594,460	1,718,194	1,846,389
Corridor 5C		1,360,849	1,566,055	1,836,622
Total Estimated Annual Costs				
Corridor 1A (Stage 1 - Expand CRA)	21,988			
Corridor 1A (Stage 2 - New System)***		35,097		
Corridor 3A		42,985	56,695	70,375
Corridor 3B		54,086	70,652	87,218
Corridor 5A		45,088	59,458	73,831
Corridor 5C		56,724	74,172	91,623

*All costs are in 1996 dollars. Costs include water treatment costs.

**Estimated cost represents "best case" scenario in terms of existing CRA hydraulic conditions, as discussed in Subsection 7.1.2. Refer to Subsection 11.1.1 for discussion of Stage 1 development cost range.

***Total annual transfer volume is 500,000 AF; this includes 200,000 AF expansion of existing CRA (Stage 1) and a new parallel system with a capacity of 300,000 AF (Stage 2).

required to the existing pumping plants. The relationships between total pumping plant discharge and net head have not been established. Therefore, the actual capability of the pumping plants to deliver the required flows under somewhat greater total head conditions than presently exist is unknown. A potential consequence may be a reduced transfer capability below the desired 200,000 AF.

Under less favorable CRA hydraulic conditions, the ability of the Iron Mountain and Hinds Pumping Plants to deliver the increased flows is doubtful due to even greater total head conditions. Several options for increasing the discharge capacity of these pumping plants were identified in Section 7.0, including replacing the existing impellers with new impellers of higher discharge capacity, installation of cycloconverters, or installation of load commutating inverter (LCI) systems. However, evaluating the practicality of any of these alternatives is beyond the scope of this study.

For the less favorable hydraulic conditions, construction of a new 18.3 mile long tunnel parallel to the Coachella Tunnel located downstream from Hinds, and construction of a new 8.3 mile long tunnel parallel to the Iron Mountain Tunnel located downstream from the Iron Mountain Pumping Plant was considered to be required to reduce total pumping head. Additionally, construction of a new 6 mile long tunnel parallel to the Whipple Mountain Tunnel located downstream from Copper Basin Reservoir was considered to be required to eliminate the need to increase the water surface elevation within Copper Basin Reservoir. The estimated total capital cost for these tunnels is approximately $540 million. The addition of this cost to the best case scenario costs provided in Table ES-1 results in estimated Stage 1 cost of approximately $1,430,000,000. This estimated cost is considered to represent the likely upper limit of Stage 1 development costs

The wide range of estimated costs for Stage 1 development reflects the cost sensitivity of the large and complex CRA system to existing hydraulic conditions. As a result, additional design evaluations would be appropriate to refine the system hydraulic conditions and estimated Stage 1 development costs. A reduced annual transfer capability should also be evaluated. Clearly, the most cost-effective system would maximize annual transfer capability while minimizing the costs for modifications to the CRA. Therefore, any additional evaluations should compare the costs for systems having reduced transfer capability with the incremental costs associated with providing the full 200,000 AF.

ES.11.2 Water Treatment Costs

Table ES-2 presents the estimated capital and annual costs for water treatment associated with Corridor 1A. Estimated water treatment costs for Corridors 3A, 3B, 5A, and 5C are provided in Table ES-3. These costs are included in the summary of estimated costs in Table ES-1.

Table ES-2
Estimated Water Treatment Costs--Corridor 1A*

Item	Stage 1	Stage 2**
Annual Transfer	200,000 AF	300,000 AF
Effluent TDS	500 mg/l	500 mg/l
Deliverable Volume	181,400 AF	272,100 AF
Total Estimated Capital Costs	$103,398,000	$155,097,000
Total Estimated Annual Costs	$8,834,000	$13,251,000

*All costs are in 1996 dollars.
**Total annual transfer volume is 500,000 AF; this includes 200,000 AF expansion of existing CRA (Stage 1) and a new parallel system with a capacity of 300,000 AF (Stage 2).

Table ES-3
Estimated Water Treatment Costs--Corridors 3A, 3B, 5A, and 5C*

Item			
Annual Transfer	300,000 AF	400,000 AF	500,000 AF
Effluent TDS	500 mg/l	500 mg/l	500 mg/l
Deliverable Volume	260,100 AF	346,800 AF	433,500 AF
Total Estimated Capital Costs	$197,400,000	$263,200,000	$329,000,000
Total Estimated Annual Costs	$18,100,000	$24,100,000	$30,100,000

*All costs are in 1996 dollars.

ES.11.3 Other Corridor Costs

Storage Reservoirs

A storage reservoir will be required for each corridor to provide daily operational storage, to balance variations in monthly supply and demand, and to provide storage for periods of scheduled and unscheduled pumping outages. The costs for storage reservoirs are accounted for in the Emergency Storage Project cost estimates ("Emergency Storage

Project-Draft Opinion of Probable Phase II System Costs," GEI Consultants, Inc , February 8, 1995), and are, therefore, not included in the corridor cost estimates shown in Table ES-1

Corridors 1A and 3A would utilize the proposed Moosa Reservoir for storage. Corridors 3B, 5A, and 5C would utilize an expansion of San Vicente Reservoir. The ESP cost estimate indicates a cost of $294,400,000 for Moosa Reservoir based on an active storage capacity of 68,000 acre-feet. This active capacity approximately corresponds to the required 67,000 acre-feet active capacity identified in Section 7.4 of this study. The ESP cost estimate indicates a cost of $131,200,000 to expand San Vicente Reservoir by 68,000 acre-feet. These costs are in late 1994 dollars and include contingency, engineering, and administration allowances, and cost offsets.

Beeler Canyon System

Corridors 3B, 5A, and 5C utilize the Beeler Canyon System from San Vicente Reservoir to the Second Aqueduct. The Beeler Canyon System, as developed for the Emergency Storage Project evaluations, originates on the west side of San Vicente Reservoir and terminates at the Second Aqueduct near Mercy Road. A pumping plant near San Vicente Reservoir would be provided to lift the design flows to a sufficient elevation to match operating heads at the Second Aqueduct. The costs for these facilities are included in the ESP cost estimates and are, therefore, not included in the corridor cost estimates shown in Table ES-1.

The ESP cost estimate indicates a cost of $135,600,000 for the Beeler Canyon System and a cost of $46,800,000 for the San Vicente Pumping Station. These costs are in late 1994 dollars and include contingency, engineering, and administration allowances, and cost offsets.

Canal Extension from Drop No. 1 to Colorado River

The opinions of probable cost presented in this study are based on Corridors 3A, 3B, 5A, and 5C extending from Drop No. 1 on the All-American Canal to the Second Aqueduct. However, total capital costs were also estimated for extending the corridors from Drop No. 1 to the Colorado River as follows:

Annual Transfer Volume	Estimated Canal Extension Cost
300,000 AF	$51,274,000
400,000 AF	$54,033,000
500,000 AF	$56,586,000

These estimated costs include canal construction land acquisition, environmental permitting and mitigation, and contingency and indirect cost allowances.

ES.12 Staging Opportunities

Possible strategies to stage construction of the alternative corridors were evaluated to defer capital cost. Estimated cash flows for each practical construction scenario are provided in Section 12.0 of this study. The following summarizes the evaluation of staging opportunities

Corridor 1A

Corridor 1A is an excellent candidate for staging of construction. Stage 1 would consist of modifications to the CRA to deliver about 200,000 AF. Later, as demands increase, Stage 2 would consist of constructing a parallel system to the existing CRA sized to deliver 300,000 AF, for a total increased capacity of 500,000 AF.

Corridor 3A

Corridor 3A consists of some 90 miles of canal, over 30 miles of pipeline, and about 40 miles of tunnel. Three pumping plants are also associated with Corridor 3A. The evaluation for staged construction of Corridor 3A examined the opportunity for phased construction of each of these major components. The estimated capital costs for the canal component are less than 10 percent of the total capital cost for Corridor 3A for all delivery options. Furthermore, the canal component increases only by about 15 percent for the range of transfer volumes considered. The canal component thus does not offer significant opportunities for staging of construction to defer significant capital costs.

Although representing a slightly larger percentage of total capital cost, pipelines still do not offer a significant opportunity for staging. In fact, the construction of two smaller diameter pipelines would result in a significant increase in capital cost

The tunnel component is the single biggest cost component for Corridor 3A. For constructibility reasons, a minimum excavated tunnel of 12 feet diameter has been selected. This tunnel diameter, even when lined for geologic or internal pressure considerations, has sufficient hydraulic capacity to accommodate all flows up to and including the design flow for a 500,000 AF transfer. Therefore, the tunnel costs are independent of proposed transfer volume and no opportunity to stage tunnel construction exists.

Pumping plants are good candidates for staging. Bays can be added to the pump-house to accommodate additional pumps as the volume of transfer water increases. However, pumping plant costs represent less than 10 percent of the total capital cost, and staging would not significantly defer capital costs.

Opportunities for classical staging on Corridor 3A that result in significant cost deferral do not exist

Corridor 3B

Corridor 3B has component characteristics similar to 3A except the tunnel component is less than the pipeline. Corridor 3B does have considerably more pumping head and thus has two more pumping plants than 3A. Two cash flow scenarios are presented in Section 12.0 for Corridor 3B. The first is based on full initial development of a 500,000 AF system. The second is based on deferring capital costs of pipeline and pumping plant components.

Corridor 5A

Corridor 5A, due to its long tunnel component and low pumping head, offers no significant opportunity for staging of construction.

Corridor 5C

Corridor 5C is principally comprised of pipeline. Similar to 3B, Corridor 5C has a large pumping head and 5 pumping plants. Two cash flow scenarios were developed for Corridor 5C. The first is based on full initial development of a 500,000 AF system, and the second is based on deferring capital costs of pipeline and pumping plant components.

ES.13 Decision Analysis

There are cost risks associated with every project. The key is not to totally avoid this risk, but to be aware of its characteristics and manage it. A decision analysis was performed to provide a statistical interpretation of cost risk associated with construction and operation of the Water Transfer System, and to provide a basis for prudent interpretation of design decisions. The capital cost and annual costs for Corridors 3A, 3B, 5A, and 5C were evaluated as part of the decision analysis. Stage 1 development of Corridor 1A (CRA expansion) was not included in the decision analysis because of the wide range of estimated costs which reflects the cost sensitivity of the large and complex CRA system to existing hydraulic conditions.

A traditional EXCEL spreadsheet was constructed to represent the framework and relationships of the technical and financial elements. The spreadsheet represents a fully functional deterministic analysis of the design and financial elements. Through the use of a commercial overlay or "add-in" program, deterministic elements of the spreadsheet were then replaced with probability density functions that reflect each member's full probabilistic variability and quality characteristics. Two types of probability density functions were used: uniform and triangular. The uniform density function is defined by the lowest value considered possible and the highest value considered possible, where every value in between is equally likely to happen. The triangular density function is defined by the lowest value possible, the highest value possible, and the most likely value. The choice of uniform or triangular probability density function for a particular cost component was the decision of the Black & Veatch project team expert in the particular area. The choice was based on the expert's perception of the uncertainty of the cost component. The resulting spreadsheet has almost the full power of a custom built Monte Carlo simulator, and presents not only an "average" result, but the full representation of an Owner's cost risk and opportunity characteristics. The probability density functions allow quantifications of cost risk on selected parameters: pipelines, tunnels, pumping plants, power generation/ pressure control facilities, water treatment facilities, environmental permitting and mitigation, total capital cost, and annual costs for all corridors and transfer volumes. For each possible output, an associated probability is provided, and risk exposure can be determined.

Monte Carlo simulations were run consisting of 5,000 trials. This value was chosen because it provided values for the standard error of the mean that were below 0.5 percent of the expected value. The estimated cost variability resulting from the simulations are presented as probability of nonexceedance tables in Section 13.0.

1.0 Introduction

1.0 Introduction

1.1 Background

The San Diego County Water Authority (Authority) was organized on June 9, 1944, to provide a safe and reliable water supply to the San Diego region. The Authority consists of 24 member agencies, including 6 cities, 16 special districts, and the Pendleton Military Reservation. The County of San Diego is a nonvoting, ex-officio member of the Authority.

A 34 member Board of Directors governs the Authority. The General Manager and administrative staff implement the policies approved by the Board of Directors and handle the agency's day-to-day operations.

The estimated population in San Diego County is 2.6 million people, 97 percent of which live within the Authority's service area. The service area lies within the foothills and coastal areas of the western third of San Diego County, encompassing approximately 907,630 acres. As a wholesaling entity, the Authority has no retail customers, but delivers water to its member agencies who provide it to their customers. The Authority supplies as much as 95 percent of the county's water supply, purchasing all of its water from the Metropolitan Water District of Southern California (MWD).

The Authority takes delivery of water from the MWD in five pipelines. Water is conveyed and distributed through more than 230 miles of pipeline to the Authority's 24 member agencies through 100 service connections. The portions of the pipelines controlled by the Authority start at MWD's delivery points near San Diego County's northern border and extend south in two separate corridors that are commonly referred to as aqueducts.

The 2100 Plan. The 2100 Plan is a program the Authority is investigating to provide a reliable, high quality, supplemental water supply sufficient to meet the needs of the San Diego County Water Authority's service area through the year 2100. The Authority and the Imperial Irrigation District (IID) signed a Memorandum of Understanding in September 1995 to negotiate the terms of an agreement with a goal of transferring up to 500,000 AF per year from IID to the Authority. One of the major issues in the negotiations is the cost to the Authority of purchasing and transporting this water to its service area.

1.2 Purpose and Study Organization

The purpose of this feasibility-level engineering study is to develop a range of costs of facilities to transfer water from the Imperial Irrigation District to the San Diego County Water Authority.

To meet the objectives of this study, an identification of alternatives is required. The establishment of alternate corridors is presented in Section 2.0. In keeping with the purpose of this report, alternate corridors are established on a thematic basis in order to allow examination of technical and environmental factors which could impact the costs of delivered water from a transfer of IID water to San Diego County.

Section 3.0 presents an assessment of the land use characteristics of each corridor. Geologic and environmental considerations are presented in Sections 4.0 and 10.0, respectively.

Energy costs and energy management strategies are important aspects in the determination of the costs of delivering water. Section 5.0 evaluates various energy management strategies. Section 8.0 evaluates the availability and estimated costs of future power and energy. Additionally, this section evaluates the ability of the existing regional transmission facilities to deliver the additional increment of power needed. Energy prices in the US are directly tied to the availability and cost of natural gas. Section 9.0 presents an evaluation of the natural gas market.

Water quality, treatment, and brine disposal issues are addressed in Section 6.0 including estimates of the costs of achieving the desired water quality. Engineering aspects of the alternate corridors are found in Section 7.0. This includes hydraulic analysis, integration with IID and SDCWA systems, and concept designs of the major features such as:

- Canals.
- Pipelines.
- Tunnels.
- Storage Facilities.
- Pumping Plants.
- Power Generating Facilities.
- Transmission Lines.

These concept designs serve as a basis for the capital and first year annual operating costs that are presented in Section 11.0.

Finally, Section 12.0 investigates the issue of staged development and Section 13.0 evaluates on a probabilistic basis the risk of cost variances.

As a whole, the various sections represent a comprehensive evaluation of the likely range of costs for transferring water from IID to San Diego County. The Authority can use this data to evaluate the economic feasibility of such a program as input to their decision whether or not to proceed with further evaluations.

2.0 Alternate Corridors

This section presents the corridor selection process and provides generalized descriptions of the alternate corridors selected for evaluation. In selecting alternate corridors, several key attraction and avoidance criteria were used to guide the process. These key criteria and associated goals are presented in Table 2-1.

System Integration is an attraction criteria. Corridors will naturally be attracted to key elements in the SDCWA and IID systems in order to meet the goal of efficient integration. Alternatively, Faults/Geologic Hazards is an avoidance criteria. Corridors which avoid faults and other geologic hazards will meet this goal. The following sections discuss the corridor selection process in more detail.

2.1 Corridor Selection

An avoidance approach was used to meet the goals of the Faults/Geologic Hazards and Environmental/Land Use criteria as shown in Table 2-1. Potential corridors were selected to avoid the following:

- Crossing faults in tunnels.
- Tunnels in areas of known geothermal aquifers.
- Indian reservations.
- Military installations.
- Wilderness areas.

The remaining criteria and goals are cost based. Potential corridors were selected to satisfy the attraction goals of System Integration and the avoidance goals of the Faults/Geologic Hazards and Environmental/Land Use criteria. Five alternate corridors were selected to represent the potential range of capital and annual costs for the feasibility level engineering study. A description of the five corridors follows, with a discussion of the potential cost advantages of each.

2.2 Corridor Descriptions

2.2.1 Corridor 1A

Corridor 1A begins at Lake Havasu and parallels the Colorado River Aqueduct and San Diego Canal to Lake Skinner. From Lake Skinner to the Twin Oaks Diversion Structure (TODS), it is envisioned that the Authority's existing pipelines in the Second Aqueduct and future Pipeline 6 will convey the planned flow. This alternative will consist of approximately 240 miles of canals, pipelines, siphons, and tunnels from Lake Havasu to Lake Skinner.

Table 2-1
Corridor Selection Criteria

Criteria	Goal
System Integration	Efficient integration of the Water Conveyance System to both SDCWA and IID facilities.
Faults/Geologic Hazards	Avoid crossing major active faults in tunnel segments due to the possibility of intersecting geothermal aquifers and reduce the risk of tunnel rupture. Avoid other geologic hazards to the extent possible, particularly landslide areas near tunnel portals and pipeline segments.
Topography	Minimize the total lift required to deliver water from IID to the SDCWA system facilities.
Environmental/ Land Use	Avoid fatal flaws, significant permitting obstacles, and extreme mitigation costs.
Capital Cost	Minimize the capital cost of facilities while minimizing the risk of budget overruns.
Energy Cost	Minimize the energy costs while minimizing the risks of budget overruns.
Water Quality	Achieve a delivered water quality comparable to that from other supply alternatives at a minimal cost while minimizing risks of budget overruns.

Corridor 1A maximizes integration with the Authority's existing conveyance system and will have a higher pretreatment water quality than sources from IID This corridor also establishes a basis of comparison against the other four corridors that convey water from the Imperial Irrigation District facilities.

2.2.2 Corridors 3A and 3B

Corridors 3A and 3B provide the opportunity to compare the range of costs for alternate corridors extending from IID to the Second Aqueduct at either the TODS or Mercy Road. Each corridor contains segments of canals, pipelines, and tunnels. Pumping stations are required along each corridor to lift the water 2,000 and 4,160 feet for Corridors 3A and 3B, respectively. Corridors 3A and 3B will maximize integration with the Authority's planned facilities at TODS or Mercy Road and the IID system.

Corridor 3A begins at Drop No. 1 on the All-American Canal and parallels the All-American, Westside Main, and Thistle Canals to the southwest side of the Salton Sea to a point near the intersection on Highway 78 and San Felipe Creek. At this point, the corridor extends westerly along Highway 78 passing through Lower Borrego Valley. West of Desert Lodge, a 42 mile long tunnel extends westerly past Ranchita and south of Lake Henshaw, passing south of Moosa Canyon and terminating at the east side of Interstate 15. A short tunnel under I-15 and a 2 mile long tunnel segment would terminate the corridor at the TODS. Water storage would be provided in the proposed Moosa Reservoir, located in Moosa Canyon. The total length of this corridor is approximately 171 miles.

Corridor 3B begins at Drop No. 1 on the All-American Canal and parallels the All-American, Westside Main, and Thistle Canals to the southwest side of the Salton Sea to a point near the intersection on Highway 78 and San Felipe Creek. At this point, the corridor extends westerly along Highway 78 passing through Lower Borrego Valley to Sentenac Canyon. A short 2 mile tunnel would be constructed parallel to Highway 78 to bypass a narrow canyon on San Felipe Creek. From the west tunnel portal, the corridor extends southwesterly to Banner. From Banner, a 23 mile tunnel extends to San Vicente Reservoir.

The corridor would utilize the Beeler Canyon tunnel/pipeline system between San Vicente Reservoir and the Second Aqueduct at Mercy Road. The Beeler Canyon System is described in Subsection 2.2.5. The total length of this corridor is approximately 173 miles.

2.2.3 Corridor 5A

Corridor 5A was selected because it is the shortest at approximately 140 miles and offers predominately all tunnel construction. Corridor 5A begins at Drop No. 1 on the All-American Canal and parallels the All-American to the Westside Main Canal, then extends north along the Westside Main Canal to Dixieland. The corridor extends westerly and parallels the San Diego and Arizona Eastern Railroad through Ocotillo to the base of the Jacumba Mountains. From this point, a tunnel would extend in a northwesterly direction through Chocolate Canyon to San Vicente Reservoir. The corridor would utilize the Beeler Canyon System between San Vicente Reservoir and the Second Aqueduct at Mercy Road.

2.2.4 Corridor 5C

Corridor 5C uses predominately open trench construction thus providing a conveyance system that is nearly entirely pipeline from the All-American Canal to San Vicente Reservoir. The open cut construction satisfies the capital cost/risk criteria, with the goal to minimize the capital cost of facilities while minimizing risks of budget overruns.

This corridor begins at Drop No. 1 and parallels the All-American Canal to its terminus. At this location, the corridor extends west through privately owned land for a short distance, then crosses BLM land. The route intersects SR 98 and follows the right-of-way to the community of Ocotillo. From Ocotillo, the route generally parallels SR 94 to Oasis, then westerly to Jacumba, and parallels the United States and Mexico border to Campo. At Campo, the route follows a northwesterly alignment south of Barrett and Loveland Reservoirs, west of the City of Alpine to Chocolate Canyon south of El Capitan Reservoir. In Chocolate Canyon, the corridor heads northwesterly to San Vicente Reservoir. The corridor would utilize the Beeler Canyon System between San Vicente Reservoir and the Second Aqueduct at Mercy Road. The total length of this corridor is approximately 150 miles.

2.2.5 Beeler Canyon System

Corridors 3B, 5A, and 5C utilize the Beeler Canyon System from San Vicente Reservoir to the Second Aqueduct. The Beeler Canyon System, as developed for the Emergency Storage Project evaluations, originates on the west side of San Vicente Reservoir and terminates at the Second Aqueduct near Mercy Road. A pumping plant near San Vicente is required to lift the design flows to a sufficient elevation to match operating heads at the Second Aqueduct and to account for the headloss along approximately 10 miles of tunnel and 1 mile of pipeline. The tunnel as proposed will be constructed with six portals, one serving as a diversion structure to the R. M. Levy Filtration Plant in the Helix Water District's service area.

A summary of the corridor key characteristics is presented in Table 2-2. For Corridor 1A, key characteristics are provided for the corridor extending between Lake Havasu and Lake Skinner. For Corridors 3A, 3B, 5A, and 5C, key characteristics are provided for the corridors extending from Drop 1 on the All-American Canal to the Second Aqueduct at either the Twin Oaks Diversion Structure (Corridor 3A) or Mercy Road (Corridors 3B, 5A, and 5C). A map showing the alternate corridors is provided as Figure 2-1.

2.2.6 Potential Extension to Colorado River

As indicated above, Corridors 3A, 3B, 5A, and 5C begin at Drop 1 on the AAC. However, consideration is also given in this study to extending each of these corridors eastward with a new canal aligned parallel to the AAC between Drop 1 and the Colorado River at Imperial Dam, an additional distance of approximately 36 miles. This potential corridor extension may offer operational and water quality benefits to the Authority when compared to use of the AAC between Drop 1 and the Colorado River. Additionally, seepage losses would be reduced by virtue of the canal lining.

2.2.7 Evaluation Limits

Feasibility-level engineering and environmental evaluations have been performed for Corridors 3A, 3B, 5A, and 5C to estimate the range of costs associated with the water transfer facilities. Environmental evaluations include land use assessments, geologic characterizations, and assessments of biological and cultural resource permitting issues. These evaluations include the corridors between Drop 1 on the AAC to the Second Aqueduct, as well as the potential corridor extension to the Colorado River.

An abbreviated evaluation was performed for Corridor 1A compared to the other corridor evaluations, with the work scope being sufficient to estimate the range of costs associated with the transfer facilities. Significant geotechnical, geologic, and seismic issues of this corridor were characterized, however, land use and environmental evaluations were not performed.

Table 2-2
Corridor Key Characteristics

Characteristic	1A	3A	3B	5A	5C
Max Inv Elev, feet	1,400	1,150	2,860	1,150	4,050
Total Head, feet*	1,662	2,000	4,180	2,180	4,580
Hydro Net Head, feet	0	0	2,100	0	2,350
Total Length, miles	238.5	170.9	172.5	140.3	150.0
Canal, miles	81.4	91.0	91.0	56.2	44.3
Siphon, miles	19.8	2.0	2.0	1.8	1.7
Tunnel, miles**	89.5	44.4	36.5	50.8	17.0
Pipeline, miles**	47.8	33.5	43.0	31.5	87.0

*Corridors 3B, 5A, and 5C include 580 feet total head for Beeler Canyon Tunnel/Pipeline System.

**Corridors 3B, 5A, and 5C include length of Beeler Canyon Tunnel/Pipeline.